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Neuropsychological Effects of Interactive Physical and Cognitive Exercise: Increasing the Mental Challenge

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By

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ABSTRACT

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In the past decade there has been a strong desire to implement more enjoyable, interactive video game experiences to enhance an individual's exercise performance. In addition, virtual reality exercise has been utilized to create a more pleasurable experience for older adults suffering from dementia. Best (2012) defined exergaming as, "a new generation of video games that stimulate a more active, whole-body gaming experience." A recent study found that exergaming, when compared to stationary biking, can improve cognition among the older population suffering from cognitive decline (Anderson-Hanley et al., 2012). In addition, working memory training also leads to a significant improvement on tests of executive functioning (Chein and Morrison, 2010). The purpose of the current study was to determine whether combining exergaming with working memory training will enhance cognitive functioning more than each of these interventions separately. Participants were randomly assigned to one of five conditions: 1) Cybercycling (Low ACE), 2) Cycling with a Blank Screen, 5) Effortful Cybercycling (High ACE), 6) Working Memory Training, or 7) a videogame condition. Participants were given neuropsychological tests pre and post intervention, and were assigned to a 20 minute acute bout intervention. In addition, participants were given a Psychological Stress Measure (Tessier,R. et al., 1990) as well as a Flow Questionnaire post-intervention (Payne et al. 2012) to determine their overall mental

state. There was no significant time by group interaction from any of the three measures: Trails 2, Stroop C, or Digit Span Backward. Contrary to the initial hypothesis, the effortful cybercycling condition did not reveal great improvement on any of these tests. However, we did find that participants in the effortful cybercycling condition had higher stress levels and were less likely to reach a flow state when compared to the cybercycling condition. This could be due to the difficulty and nature of the task. However, increased participants in each condition are needed to determine whether there is a significant difference between these two groups.

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INTRODUCTION

Exercise has become a major factor contributing to the improvement of motor memory (Roig et al., 2012), overall health, and the prevention of cognitive declination (Anderson-Hanley et al., 2012). In addition, prior research has found that cognitive interventions, such as a working memory training task, also have cognitive benefits that prolong the deterioration of an individual's memory (Blumen et al., 2010). One recent study conducted by Anderson-Hanley and colleagues (2012) found possible cognitive benefits when combining these two components - physical exercise and an additional mental task (high ACE – aerobic and cognitive exercise). The current study will aim to explore the parameters for maximizing the cognitive benefit while combining two tasks at one time. Researchers will examine which combination of mental and physical tasks will display the most improvement on tests of executive functioning.

The Overall Benefits of Exercise

Experts have become extremely concerned with the abrupt increase in obesity among children particularly in developing countries. This epidemic is leading to a rapid increase in researchers implementing exercise plans as a way to inform the world about this extensive problem. The World Health Organization (WHO) has deemed childhood obesity to be the most disastrous health concern of the twenty-first century. Obesity is currently being considered one of the primary causes of additional health issues such as diabetes, acute coronary heart disease, and colon cancer. The WHO has begun implementing a strategic program to assist in healthy dieting and weight loss among the younger generation. They have suggested that children should participate in a minimum of sixty minutes of moderate-vigorous exercise each day, depending upon the child's abilities. Additionally, it is imperative that parents, administrators of the school and the children are collectively on board.

Although weight loss has become a major reason for the implementation of work-out programs, exercise has also been found to improve the mental state and increase the cognitive functioning of individuals throughout all stages of life. Davis and colleagues (2011) examined the effect of exercise on overweight children through a randomized controlled trial (RCT). They hypothesized that obese children would have a greater improvement in executive functioning following exercise than children who were placed in a control condition. Children who met the criteria for inactivity and overweight were randomly assigned to one of three conditions: no exercise, low exercise (20 minutes per day) or high exercise (40 minutes per day). Prior to the intervention, neuropsychological testing and an fMRI were carried out to assess the participant's baseline executive functioning. Following the three month exercise procedure, the participant was again cognitively assessed and was given an fMRI to develop an overall picture of the brain as a result of the exercise routine. Cognitive results determined that academic performance did in fact improve following the exercise intervention. Executive functioning and math scores of the children increased tremendously. In addition, the fMRI displayed an increase in neuronal connections which could ultimately be a result of the dramatic increase in physical activity (Davis et al., 2011). These overall improvements due to physical activity are critical to ensure that children's cognitive abilities are enhanced. In addition, this study provides evidence to support the claim that physical exercise leads to increased prefrontal cortex activity in the brain. This area of the brain deals with executive functioning which is involved with planning, decision making, and higher order cognitive behaviors. Researchers have found increased neurophysiological benefits of physical exercise on children suffering from obesity in the modern world (Davis et al., 2011). These findings support my plan to examine the overall effects when combining exercise and cognitive tasks to determine the cognitive benefits.

Regular exercise has become a vital component in stabilizing the mental and emotional health of individuals throughout the world. Due to the overarching concerns involving the obesity epidemic, little attention has been given to the improvements of cognitive health as a result of exercise (Hillman, Erikson & Kramer, 2008). However, the data that has recently been collected reveals a positive relationship between exercise and the brain functioning of school aged children. Perceptual skills, intelligence quotient, achievement, verbal tests, mathematic tests, memory, developmental level and academic readiness were eight variables that determined the cognitive performance of the children. Hillman et al. (2008) argue that the findings suggest an importance in early exercise intervention as a means of improving or maintaining a high level of cognitive functioning throughout one's lifespan.

Effects of Physical Activity on Cognition:

Although technological advancements are seen as having a positive effect on society and impacting the way in which people interact with one another on a daily basis, researchers have also been arguing that computers and videogames are detrimental to the health of young children. In addition to the increased laziness of children, throughout many industrialized societies we are seeing a common shift in the cognitive health of young children and adults (Hillman, Erickson & Kramer, 2008). Many children within these advanced countries are less concerned about the environmental aspects of play, and more interested in establishing relationships with individuals through video gaming. Although this declination in cognition is being seen worldwide, research has found a strong positive correlation between physical activity of young children and their academic achievements in school. These findings suggest that parents, school educators, and healthcare providers should advocate for daily physical activity to increase the cognitive functioning of young children which will ultimately lead to improvements in brain functioning in the future. Instead of using computerized gaming systems as a way to control children, adults should be encouraging physical activity to physically and cognitively impact them in a positive direction.

Traditional physical activity has been found to limit the deterioration of memory in elderly adults, which is a substantial improvement in the cognitive realm. The prevention of cognitive decline is becoming a growing concern among the middle aged and elderly population. As a result of the gradual climb in life expectancy over the years, an increase in cognitive deterioration has also become substantially noticeable (Naqvi et al., 2013). Through the use of epidemiological studies as a way to observe the cognitive state of the elderly population, researchers have found that intellectual engagement, social interaction, diet, and physical activity are factors that contribute to the reduction in risk of neurodegenerative disorders (Hillman et al., 2008). Recently, doctors have begun implementing pharmacologic and hormonal interventions; however, there is no strong evidence of improved cognitive performance (Naqvi et al. 2013). On the other hand, Naqvi and colleagues (2013) reviewed prior studies examining the positive effects of exercise and cognitive training in terms of improved cognition. Based upon three separate Randomized Control Trials, these researchers found that there was a benefit in executive functioning among a group of participants due to resistance training and exercise.

Chang and colleagues (2012) also found similar results regarding the positive effects of a single session of exercise on cognitive performance. Through the examination of 79 studies within the literature, this broad review enabled them to incorporate data based upon participants of all ages and realms of society. The primary purpose of this overall examination was to allow for the effects of exercise on brain functioning to be researched on an extensive level. Several limitations arise from this type of review, for the variables are inconsistent from study to study.

For example, the time of day and place of exercise can be a potential factor in altering the effects of exercise on the mind. Chang and colleagues (2012) concluded from the contribution of various sources, that exercise intensity played a substantial role in determining the effects of working out. High intensity exercise has the greatest effect on heart rate, and other physiological mechanisms, which is vital in the current study. The stress of reaching ones target heart rate is important; because higher intensity exercises in acute bouts are what lead to cognitive improvement.

For the past decade, researchers have made it their mission to improve the psychological and cognitive well-being of all individuals. They have found that exercise is the key to success and can be attributed to the overall increase in cognition and affective experience in children of all ages. A moderate bout of exercise ranging from 5 to 30 minutes can tremendously impact the cognitive and psychological functioning of an individual. Hillman, Snook, and Jerome (2003) examined the event-related potentials (ERP) associated with college students after thirty minutes of treadmill exercise. They used EEG to determine that there was greater P3 amplitude, which could potentially explain the increases in executive functioning and decision making following a single bout of exercise. Based upon this prior research, Hogan, Mata, and Carstensen (2013) investigated these concepts by conducting an experiment which included 144 participants aged 19-93. They wanted to understand how exercise differs between age groups and whether the improvement of cognitive functioning can be dependent upon how old the individual is. The participants were categorized based upon their age group, and then randomly assigned to either an exercise condition or a control condition. Hogan and colleagues (2013) found evidence to support the claim that exercise has a significant effect on affective experience as well as cognitive performance. The current study is hoping to enhance the cognitive performance of individuals through exercise when combined with additional techniques.

Effects of Exergaming (high ACE) on Cognition

In the past decade there has been a dramatic shift and expansion in the way individuals undergo physical exercise to maintain healthy habits. Due to the younger generations desire to play videogames, there has been significant work to integrate physical activities into virtual reality games. This would ultimately increase the entertainment portion of exercise as well as motivate individuals who lead sedentary lives (Maillot, Perrot, and Hartley, 2011). This idea began with Nintendo's Wii Sports and has become more reality driven through cybercycling on a stationary bike (Yim and Graham, 2007). Nintendo Wii Sports has given players the ability to mentally simulate sporting events by increasing the cognitive and physical demands of the participant. Instead of solely sitting in front of the computer screen, players had to engage in the game and mentally prepare themselves for the physical activities that would allow them to succeed and continue to the subsequent level (Maillot, Perrot and Hartley, 2012). Exercise combined with videogames developed due to the strong appeal for virtual reality and computer-aided games. For example, 'Life is a Village' was one of the first exergames in addition to Wii Sports and takes place on a stationary bicycle. This game gives individuals a task that they need to complete and provides them with specific goals to improve their overall fitness. The player's core goal is to build a village by navigating through the land and collecting various resources. Because of the ability to steer and pedal harder to increase speed, these videogames enabled participants to feel more present and exert more effort in the virtual world.

Traditional physical activity has been found to extensively improve the overall health of an individual. From prevention against obesity to stroke and diabetes, many people are seeing beneficial effects of participating in various physical activities (Warburton et al., 2007). Researchers have questioned whether an additional video gaming component will increase the benefits of exercise. This study examines the physiological effects of high ACE through a six week intervention. Fourteen participants were assigned to either the experimental condition (High ACE) or the control condition (stationary cycling – *Low ACE*), and carried out a specific regimented training for a total of 6 months. Participants in the high ACE condition were directed to exercise on a GameBike system while also interacting through various video games. On the other hand, the low ACE condition was asked to cycle on a traditional stationary bicycle for an allotted amount of time. In both of these conditions, the participants were allowed to determine the duration and intensity of their workout. Warburton and colleagues (2007) found significant health benefits that demonstrated positive effects of combining exercise with virtual reality video games. In the high ACE condition, there was a greater magnitude of change in resting blood pressure which could be a result of the additional interactive component. Although this study included an extremely small sample size and would need additional studies to confirm the results, there was mounting evidence that the interactive condition led to improvements in cardiovascular and musculoskeletal health.

This developing trend of integrating exercise and videogames ultimately led to the question of whether high ACE is impacting the overall cognition of these participants. Best (2012) defined exergaming as, “a new generation of videogames that stimulate a more active, whole body gaming experience”. Researchers are currently investigating whether high ACE provides a cognitive benefit in addition to fitness and weight loss. Maillot and colleagues (2012) conducted a study that assessed exergaming as a source of physical exercise, and the cognitive effects it could potentially have on the older adult population. They used the Wii Sports gaming system and hypothesized that the exergaming would improve the participants' performance on the specified sports task. In addition, they also hypothesized that there would be significant improvements on tests of executive functioning, visuospatial tasks, and processing-speed tasks (Maillot et al., 2012). Thirty-two older adults were enrolled in either a 24 hour training program that consisted of 2 hours of exergaming tasks per week for 12 weeks, or a control group (low ACE). In addition to exercising, they were also being tested through neuropsychological tests to determine the effects the long-term training was having on their cognition. Results showed that there was significant improvement post-exercise on tests of executive control and processing speed. Maillot and colleagues (2012) stated that exergames not only provide individuals with a more entertaining atmosphere for physical exercise but they also yield benefits on measures of cognition. Although it was found that high ACE conditions lead to improvement on particular measures of executive functioning, it is unclear if there is an exercise effect, gaming effect or a combination of both. The current study includes an exercise condition and a gaming condition to determine what is causing this significant improvement.

Executive functioning is a set of mental processes that use past information to determine the controlled, planned, and goal-directed behavior of an individual. It is extremely common for children to have poor executive functioning, which results in the inability to succeed in schooling both academically and behaviorally (Best, 2012). Researchers have previously found evidence to support the claim that traditional physical activity could potentially enhance executive functioning of children. In addition, videogames that require increased concentration due to the fast-paced nature also lead to enhanced cognitive and executive functioning. Best (2012) conducted a study that included the participation of thirty-three children who were assigned to one of four conditions which differed based upon their level of cognitive engagement and physical activity. The first condition was a child watching a video about Healthy Living and involved low cognitive engagement as well as low physical activity. The second condition was a stationary videogame that involved the participant to control movements of a character. This involved high cognitive engagement but low physical activity. The third condition that participants were assigned to involved exergames that had low cognitive engagement. Participants were directed to jog in place to move the character in the videogame. The last condition included high cognitive engagement as well as high physical activity, and enabled the child to become part of the videogame. In this condition, the character on the screen mirrored how the child performed. For example, when the child jumps the character in the videogame would leap over a log or other object. The child's overall cognitive performance was assessed with the Flanker task post-exercise. This study revealed evidence that a single bout of exergaming can enhance a child's overall executive functioning more than just traditional exercise alone (Best, 2012).

As the older population continues to expand, dementia and other diseases resulting in cognitive deterioration are also widening. Researchers have been attempting to create a plan that improves the quality of life of the older generation. Exercise is a factor that cognitively benefits individuals and has been found to delay the onset of dementia and additional age-related diseases. The combination of computer simulation and exercise (high ACE) is also desirable due to the strong appeal of video games and virtual reality. Anderson-Hanley and colleagues (2012) hypothesized that cybercycling would be beneficial to overall cognition and executive functioning. In this study, participants were randomly assigned to either the exergame condition (virtual reality tour paired with exercise) or the control condition (solely exercise). One hundred and two participants were recruited from 8 retirement facilities in the surrounding area; however, only 63 of these older adults completed the entire study. They were evaluated three times by neuropsychological tests that included assessment of executive functioning. These tests were the Color Trails, Stroop C, and Digit Span Backwards, and are the three primary tests that will be used in the current study. Results revealed that the high ACE condition yielded greater cognitive benefit than the low ACE condition; however, both of these groups exerted equivalent levels of effort. The current study builds upon this core belief that an additional mental component combined with exercise will ultimately lead to improvements in the cognitive realm.

Effects of Working Memory Training on Cognition

Working Memory (WM) is commonly defined as an area of mental storage that is limited in capacity but is used to process and store information which continuously enters one's memory. Prior research has found evidence to support the notion that working memory capacity predicts the higher cognition of an individual (Morrison and Chein, 2011). Many researchers have tried to enhance the cognition of individuals through training their working memory and examining the impact it has on executive functioning. Klingberg (2010) suggested that working memory capacity can be improved through intense training, which ultimately leads to neuronal alterations in the frontal and parietal lobes. Increased dopamine receptors are released as a result of working memory training, ultimately leading to an overall increase in cognitive performance.

Morrison and Chein (2011) were determined to find the level of improvement working memory training has on cognitive performance. They separated working memory training into two categories: strategy training and core training. Based upon prior literature, they wanted to identify which training approach would impact the overall working memory capacity of an individual. Strategy training utilizes working memory tasks to encode, or retrieve items from working memory, and core training involves repetition of working memory tasks. Both of these training techniques are carried out in the current study when the participant is directed to remember the amount of objects they passed on the trail while simultaneously stating where the objects are located. Morrison and Chein (2011) found evidence to support the hypothesis that working memory training does work; however, the most significant findings can be associated with the core training improving once cognitive functioning. In 2010, Morrison and Chein recruited 42 students from Temple University and randomly assigned them to either a four week working memory training condition or a condition with no mental task. Neuropsychological tests were administered pre and post intervention and results found that trained participants improved significantly on the cognitive tasks when compared to the non-trained participants. Improvement on a working memory task is expected due to a practice effect and an increase of understanding the task over time. It is imperative that in future studies these findings are generalized to everyday life to reveal the importance of training one's mental abilities outside of the laboratory.

Anguera and colleagues (2013) published a study in *Nature* which was attempting to unravel the question of multitasking. Due to the high paced modern society that exists today, many researchers wonder what determines an individual's ability to carry out more than one task at a given moment. This study analyzed the cognitive effects of attending to multiple stimuli at a time through a 3D videogame – NeuroRacer. Participants ranged from 20 to 79 years old and were randomly assigned to one of three conditions. The first two conditions involved the participants playing the videogame with a single task. In the *Drive Only* condition, the participant used a joystick to maneuver a car on a specific trail. In the *Sign Only* condition, the participant had to immediately identify when a green dot would appear on the screen. The *Sign and Drive* condition instructed the participants to move the car while simultaneously identifying when a green dot appeared. This condition is similar to the working memory only condition in the current study, for participants had to use the keyboard to navigate on the screen and perform a mentally engaging task. Anguera and colleagues (2013) found that the ability to multitask declined as participants got older. In addition, when individuals were trained in the multitasking game, their cognitive performance improved from pre to post-neuropsychological testing. This study gives rise to the importance of utilizing working memory training to improve cognition. The present study is aiming to enhance cognition through combining a working memory training task with physical exercise.

The State of Flow

The concept of flow was an optimal mental state founded by Csikszentmihalyi in 1990, and is a possible contributor to the cognitive improvements which are associated with the pairing of cybercycling and a specific degree of mental stimulation. Nakamura and Csikszentmihalyi (2009) defined flow as, “the experiential state that occurs as one approaches optimal engagement with a task, emerged from interest in describing the experience of optimal performance”. Flow is a positive state of mind that gives individuals the motivation to perform difficult tasks, and is enriched due to these particular experiences which are intellectually challenging in nature. This mental state is reached when an individual is completely absorbed in the task at hand and does not allow additional environmental stimuli to become distracting (Nakamura & Csikszentmihalyi, 2009). According to Dietrich (2004), in addition to the mind-state necessary to reach this level of mental engagement, there are neurocognitive functions within the brain that elicit one’s ability to incorporate the state of flow into a particular cognitive activity. The explicit system is the primary neural network of cognition and is housed in the frontal lobe. This area of the brain is associated with attention, planning and short term memory tasks that lead to an increase in cognitive flexibility (Dietrich, 2004). On the other hand, the implicit system is in the basal ganglia and is based directly on prior experience as well as routine behaviors. The ability to reach a state of flow is dependent upon these two separate systems. If an individual can suppress the mental awareness associated with the explicit system of cognition and completely focus on the task at hand, a state of flow will be reached.

Payne and colleagues (2011) revealed that reaching a state of flow is also dependent upon the Match Hypothesis, which states that participants with higher fluid abilities were able to experience higher levels of flow in activities of cognition. In their study, they hypothesized that, “Engaging in an activity that is more cognitively demanding will elicit higher levels of flow for those with higher fluid ability, but lower levels of flow for those with lower fluid ability” (Payne, Jackson, Noh, & Stine-Morrow, 2011). This idea is based upon the Match Hypothesis which examines the overall relationship between an individual’s state of flow and their cognitive abilities. The study included 197 older adults who were given a 34 item flow questionnaire that was developed based upon the nine dimensions that are imperative to reach this mental state (Csikszentmihalyi, 1990). This first portion of the study was utilized to determine the validity of the current flow questionnaire and whether it will correctly examine this particular mental state. Participants had to reflect upon a recently performed activity and answer questions to determine the cognitive demand of the task. They were then randomly assigned to a category: high cognitive demand or low cognitive demand. The individuals placed in the high cognitive demand group included activities such as educational activities, working, challenging mental games, or art and music. The low cognitive demand group included activities which did not require a large amount of mental effort such as television, cooking, vacation and resting (Payne, Jackson, Noh & Stine-Morrow, 2011). Their findings indicated that the Match Hypothesis was correct; for the participants who have a greater intellectual capacity indicated that they experienced higher levels of flow in cognitively demanding tasks.

Recent research has been incorporating flow as a mental state which has the potential to enhance an individual’s performance in a sport that is centered on physical exercise (Jackson, Kimlecik, Ford, & Marsh, 1998). Older athletes in various sports have indicated that this mental state is imperative to perform as best as possible in either a practice or game-like situation. Jackson and colleagues (1998) directed 398 elite athletes to complete several questionnaires assessing their flow state pre and post event. Prior studies indicated that intrinsic motivation to complete and succeed in a task is vital to reach this higher mental state (Csikszentmihalyi, 1990). This finding led to the overall basis of the study; that psychological factors such as an autotelic personality (intrinsic motivation), extrinsic motivation, goal orientation, highly perceived abilities, and competitive trait anxiety will have a significant impact on one’s ability to reach this optimal state of arousal (Jackson and colleagues, 1998). After assessing the questionnaires, there was evidence that an autotelic personality is the most important indicator of a person’s ability to reach flow. The self-determination to succeed on a given physical or cognitive task can impact the overall mental capacity of an individual.

If reaching a flow state is necessary to become completely engaged in a task and succeed in a particular activity, it is possible that this explains the increase in cognition through the combination of physical and mental exercise. Anderson-Hanley and colleagues (2011) did not incorporate the state of flow into their study of exergaming; however, it is possible that the ability of an individual to reach this mental state can impact the cognitive gains associated with the pairing of mental and physical stimulation. Prior research has examined the state of flow and revealed its ability to enhance cognition. We hypothesized that flow would play a significant role in determining the participant's performance on tests of executive functioning following a single bout of exercise and mental engagement.

The Present Study

Due to the extensive research regarding the successes of working memory training and exergaming independently on improvement of cognitive functioning, the current study is examining the effects of pairing these two variables and ultimately determining the impact it has on an individual's executive functioning. The current study is expanding upon the idea of multi-tasking as a way to improve cognitively on working memory tasks, and is attempting to understand what combination of mental exercises will have the most significant improvement on cognition.

Hypotheses:

It is expected that:

1. Executive functioning is expected to improve significantly more from pre- to post-testing in the aerobic and cognitive exercise (ACE) condition with interactive physical and more effortful mental exercise (working memory task embedded in tour; high ACE) vs. more limited mental challenge of cybercycling alone (navigating a tour; low ACE)
2. Participants in the Effortful Cybercycle condition (high ACE) would reach a greater state of flow leading to improvements on the executive functioning task. The state of flow may facilitate the relationship between cybercycling and added cognitive benefit.

METHODS

Participants

Participants in the current sample (n=77) consisted of undergraduate students from Union College in Schenectady, New York ages 17-23 years old 19.4 years (SD=1.4). There were 48 females and the remaining participants were male. Five of the participants were Hispanic, three of the participants were African-American, ten were Asian, one was Indian, and the remaining 57 were Caucasian. One student did not speak fluent English and could not read the questionnaires; therefore, that data was not used in the final sample. Participants were recruited through Freud, the college's psychological research online sign-up system. They received either $8 cash or one-hour of psychology course credit upon completion of the study. The study risks and benefits of participating were reviewed in the lab prior to beginning the study. Each participant was given the option to leave the study at any point if they felt uncomfortable or could not complete the twenty minutes of intervention that was assigned. Additionally, each participant signed an informed consent form which was approved by the Union College Human Subjects Review Board.

Design

The study ran over a five-month period, which extended from November 2013 until March 2014. Each participant was randomly assigned one of seven independent variables. These included: stationary cycling; cybercycling (stationary cycling with virtual reality game); mindful cybercycling; mindful meditation; working memory training and cybercycling (cybercycling while performing various mental tasks); working memory training (performing mental tasks only); a videogame condition. Though participants were assigned to seven different conditions, this particular study will focus on five of these variables: stationary cycling; cybercycling;

working memory training and cybercycling; working memory training; videogame condition. The results gathered from two additional variables, mindful cybercycling or mindful meditation condition, were used in a study which investigated the impact of mindful meditation on cognition (Stein, 2014). The results including those two conditions will be touched upon in an additional paper.

The conditions that involved physical activity took place on an Expresso S3R Recumbent Bike (Interactive Fitness Holdings LLC). The cybercycle condition directed the participant to complete twenty minutes of exercise while steering through a path called Evening Bliss. The stationary bike condition consisted of the participant completing a twenty minute bout of exercise while looking at a blank screen. Working memory and cybercycling combined was designed to increase the mental performance of the participants. While steering through the Evening Bliss path, lampposts and signs appeared on both sides of the pathway. The participants were asked to say out loud “right” or “left” when they approached either of these two objects. In addition, they were asked to also keep track of how many objects they passed. When they reached ten objects they were told to say “ten” out loud and start the process over again. The working memory condition involved the participants using a keyboard to navigate through the Evening Bliss pathway. This condition performed the same mental task as the previous condition; however, there was no additional exercise component. The last condition was the videogame condition which involved the participant playing a Dragon Chase game. They used a keyboard to navigate around the screen and collect various coins that were different colors based upon their point value. The participants collected coins, and depending upon the color of that coin they had to also get the subsequent dragon. After completing the game, the experimenter recorded the point value that the participant received throughout the twenty minutes of playing.

The dependent variable of the current study was executive functioning and was recorded based upon neuropsychological testing. These paper and pencil evaluations included the Color Trails IIA and IIB, Stroop Version 1, Version 2, and Digit Span Version 1 and Version 2. Each of these tests was administered to the participant before and after the study to understand whether the particular condition led to a change in cognitive functioning.

Measures

Demographic Questionnaire: This questionnaire was developed based upon prior research in the Healthy Aging & Neuropsychology Lab at Union College. It investigated standard questions about the participant's life which could ultimately impact the overall effect on the dependent variable. Some of these questions included: age, gender, ethnicity, whether or not the participant ever played a sport in high school or college. These variables are important, for they could act as a third variable within the study. In addition, several questions relevant to what was being assessed in the current study were also added to the questionnaire. For example, the amount of experience the participant had with stationary biking, videogames, or meditation. Each of these variables could impact the performance throughout the study, so it is imperative that these are each noted.

Exercise History Questionnaire (McAuley et al., 2011): This questionnaire was designed to separate the participants based upon the amount of exercise they engaged in on a daily basis. The participants were first instructed to check off the level of activity that reflected their daily pattern of physical activity. The levels of activity ranged from one to five and increased in intensity with each additional level. Level one was "inactive or little activity other than usual daily activities", and level five was "participate in aerobic exercises at a comfortable pace for over three hours per week." The participant was also asked to answer questions related to the length, intensity and reasons for exercising. They were asked to identify the type of exercise they engage in throughout the week. The options included: strength/resistance (weightlifting), flexibility (stretching), stamina/endurance (cardiovascular), or balance (yoga). This questionnaire was attempting to understand if there is a correlation between the amount of exercise the participant.

Psychological Stress Measure-9 (Tessier,R. et al., 1990): This nine-item questionnaire was used to assess the amount of stress the participant was feeling. This scale was given to the individual before and after the exercise condition to determine whether the task left the participant feeling at ease or increasingly stressed out. The participant was asked questions associated with positive and negative elements of stress. For example, question one stated: *I feel calm, which shows positive stress of the participant, and question five stated: I feel confused; my thoughts are muddled; I lack concentration and I cannot focus my attention, which shows negative stress of the participant*. The participant circled the number that best indicated the degree to which each statement applied to him/her at that moment. The scale ranged from 1=not at all, to 8=extremely. After the participant completed the Psychological Stress Measure, the examiner had to convert the scores of question 1 and question 6 because they indicated the opposite of what was being measured. For example, if the participant circled the number 1, the examiner would convert it to 8.

Flow Questionnaire (Payne et al. 2012). Payne and colleagues (2011) describe flow as a "pleasurable experiential state that occurs during full-capacity engagement in which an individual is performing at a level that is matched with the demands of the task." This questionnaire serves as a manipulation check to ensure that there are varied levels of mental engagement within each experimental condition. The questions included in this questionnaire try to establish whether or not the participant has experienced a feeling of flow throughout the exercise session. There are 16 statements based upon five subset scales (Merging of Action and Awareness, Concentration on the Task at Hand, Challenge-Skill Balance, Transformation of Time, Autotelic Experience). Each statement ranges from a scale of 1=strongly disagree to 5=strongly agree. For example, question one states: *"I performed automatically, without thinking too much, and question thirteen states: I lost my normal awareness of time."* A state of flow is reached when a participant is engaged in a higher cognitive demanding task that forces them to completely disconnect from the surrounding environment. After a preliminary check, it was found that the conditions in the current study are on a spectrum of varied mental challenge. The purpose of the study is to determine which of these conditions will be most cognitively beneficial to the participant.

Exercise Induced Feeling Inventory (Gauvin & Rejeski, 1993). The purpose of this questionnaire was to determine whether the participant exerted a sufficient amount of physical and/or mental exercise throughout the 20 minute intervention. The participant was able to self-reflect on the amount of energy that was used to complete the entire study. This inventory provided the participant with various words that could describe how they were feeling after their twenty minute exercise bout. Several of the words that were used on the questionnaire were refreshed, calm, revived, and the participant indicated how they were feeling on a scale of 0=do not feel to 4=feel very strongly. Several of the words on this inventory had to be converted because they were used to make sure that the participant was paying attention (fatigued, tired, worn-out). For example, if the participant rated one of these words a 1, this would be converted to a 3 on the point scale. In addition, the participant was also asked to indicate the amount of mental and physical effort that was used during the exercise session. The scale ranged from 0=no mental effort to 100=very challenging mental effort.

Color Trails (CTT): This is a neuropsychological task that assesses executive functioning associated with visual attention. The participants are required to complete this test pre and post exercise to evaluate their level of improvement which can be associated with their exercise performance. The pre-test forms were Color Trails 1A and Color Trails 2A, and the post-test forms were Color Trails 1B and Color Trails 2B. Prior to completing each of these tasks, there was an eight item practice trail to ensure that the participant understood the directions from the experimenter. The two tests that were given prior to exercise and the two tests after the exercise condition was completed had twenty-five items total. In Color Trails 1A, the participant was instructed to connect the dots with their pencil, in increasing order from “one to two, two to three, all the way up to twenty-five.” After successfully completing the Color Trails 1A task, the participants were then told to complete Color Trails 2A. This required the participant to also connect the dots from one to twenty-five in numerical order; however, they now had to alternate between the colors yellow and pink. There were fifty total dots on the page, but only twenty-five would be needed to complete the trail. This was the target task that was used to determine the participant's executive functioning. The Color Trails 1 and Color Trails 2 tasks were the same as the post-tests. During each of these tasks, the participants were instructed to work as fast as possible without removing their pencil from the paper, and attempting to connect the middle of one circle to the middle of the next. The working memory condition showed significant improvement on this particular task due to the visual searching and attention that was needed while performing the 20 minute intervention.

Stroop Test PROSPER version – 40 items (Stroop, 1935): This test has been widely used across cultures for many decades as a measure of interference control within a clinical setting (van Mourik, Oosterlaan, & Sergeant, 2005). Although there are various versions of the Stroop Task, the standard test which was used in the current experiment is comprised of three stimuli. Each participant completed the test in a specific order of Stroop A, Stroop B, and Stroop C. Stroop A consisted of a practice line and four additional lines that included red, green and blue colored blocks in random order. Each line was composed of ten colored blocks. The practice line was to clarify that the participant did not suffer from a disability which could ultimately inhibit their performance; this could include color blindness. The participant was instructed to say the colors of each block in order as quickly as possible until the task was successfully completed. The examinee was told to keep track of the amount of time it took for the participant to complete an entire line. If the participant did not say the accurate color, the examiner was told to circle the wrong item. The Stroop B was completed next and included a similar format as Stroop A. The task had a practice line and four additional lines that had the words red, blue and green; however, the words were printed in black ink. Stroop A and Stroop B were the two preliminary tasks that ensured the participant associated the correct words and colors with one another.

After these two trials, the participants then received Stroop C which included a practice trail and four additional lines, each composed of ten words. The words on the page were in random order and either said red, blue, or green. This task was challenging, for each word was written in a different color ink than what the word meant. For example, the word green was written in blue ink. The participants were instructed to say out loud the color of the ink, not the word that was written. This was known as the interference trial and assessed the executive functioning of the brain. During this task, the participant had to completely disengage from their automatic intuition, and ignore the word that was written on the page. All three of these paradigms were timed by the experimenter who was conducting the study.

Digit Span Forward & Backward: Participants were required to complete the Digit Span Forward and Digit Span Backwards tasks before and after their exercise condition. The Digits Forward task was used to measure the attention span of the individual, and was not used to directly test the executive functioning of the individual. Instead, this task was used as a preliminary measure to ensure that the participant was aware of their expectations on the task. The examiner read the participants a string of numbers that would increase in length, depending on how many items the participant correctly recited. The task consisted of a total of 8 different lengths of numbers, ranging from two to eight digits. Within each of the measures, two trials were included. The examiner would read a string of numbers to the participant, pausing for one second between each digit, for example: “6-9-4.” The participant would be expected to correctly repeat these digits back after the instructor was finished. If the participant got one or both of the trials correct, he/she would move on. If both of the trials in one block were cited incorrectly, the participant would be unable to move onto the next string of numbers. This gave the examinee an opportunity to receive 16 total points if they repeated all of the strings of digits correctly. The Digit Span Backward task was also set up in the same format; however, there were only seven different lengths of numbers with two trials in each. This enabled the participant to achieve 14 points if they correctly recited each item. The examiner would present the participant with a string of numbers such as, “4-1-5.” After the examiner was finished, the participant was expected to repeat these digits backward saying, “5-1-4.” The Digits Forward task was used to as a practice trial, and the Digits Backward task was the main indicator of executive functioning. The cumulative score that the participant could receive was thirty points.

Calculating Target Heart Rate: The target heart rate of each participant was determined by using the Karvonen equation (Karvonen et al., 1957). Prior to exercising, the participant was asked to hold the metal pieces located on the right and left handlebars of the stationary bike. This was used to measure the resting heart rate of the participant, and would be implemented into the equation:

Target Heart Rate = (220 – age - Resting Heart Rate) x .60 + Resting Heart Rate

During the exercise session, the participant was supposed to try and maintain exercise intensity equal to 60% of their heart rate reserve during a twenty minute exercise bout. In order to reach this target heart rate, the participant could adjust the gears to alter the pedaling resistance. Reaching the target heart rate ensured that the participant was getting the full effect of the exercise condition. Participants who were able to reach their target heart rate at any time during the exercise session were included in the sample. This was identified as a loose cutoff for the participant's target heart rate.

Procedures

The session lasted an hour, with 20 minute intervention (e.g., mental exercise, physical exercise, or combined activities), and 40 minute neuropsychological testing of executive function. When the participant arrived at the Healthy Aging and Neuropsychology Lab in Bailey Hall, they were greeted by a research assistant who was conducting the current experiment. They were first asked to read over and sign an informed consent document that outlined the study and gave their permission to take part in the study. There were six different experimenters who were conducting different conditions; therefore, a script was made to ensure that there was consistency across each exercise condition. After the participant was informed about the confidentiality and risks of the study, they were then instructed to complete the Demographic Questionnaire which was developed by a prior researcher. The participant then filled out the Exercise History Questionnaire (McAuley et al., 2011) and the Psychological Stress Measure (PSM-9) (Tessier,R. et al., 1990).

After these three questionnaires were completed by the examinee, they were then given prompting to complete several pre-neuropsychological tests. These included the Color Trails 1A and Color Trails 2A, the Stroop A, Stroop B, and Stroop C, and the pre-exercise Digits Forward and Digits Backward. The participant completed the Color Trails by using a pencil; however, the Stroop and Digit tasks were completed through verbal communication. When the participant completed the questionnaires and neuropsychological tests, they were led into the exercise room, where they would complete their twenty minute experimental condition.

The participants randomly assigned to condition 1: cybercycle only, were directed to sit on the stationary bike and pedal through a path called Evening Bliss. They were told to maintain their target heart rate by increasing the gears located on the handlebars, and steer through the trail as fast as possible. The participants assigned to the additional exercise manipulations: blank screen (condition 2), and working memory task & cybercycling (condition 5), were also instructed to do the same; however, there was a manipulation of the underlying condition. The working memory (condition 6) and videogame (condition 7) were instructed to sit in front of the computer screen and use the keyboard to navigate through the game or pathway.

After the participant completed their bout of exercise, the experimenter recorded the distance rode, average power, maximum power, mph, average heart rate, maximum heart rate and calories burned of the individual. After completing the twenty minute exercise condition, the experimenter offered the participant a few minutes of rest and a cup of water. The participants then completed several post-exercise inventories which included the *Psychological Stress Measure-9* (Tessier,R. et al., 1990), the *Flow Questionnaire* (Payne et al. 2012), and the *Exercise Induced Feeling Inventory* (Gauvin & Rejeski, 1993). After the questionnaires were successfully completed, the post-exercise neuropsychological tests were administered. These included the Color Trails 1B and Color Trails 2B, Stroop A, Stroop B, Stroop C, and the post-exercise Digit Span Forward and Digit Span Backward. Although each of these tests had the same strategy, alternate forms were used to limit the practice effects. After the testing was completed, the participants were debriefed and compensated with either cash or psychology course credit.

Statistical Analysis

Data collected was analyzed using Microsoft Excel and the Statistical Package for the Social Sciences (SPSS v. 12.0). Repeated measures ANOVAs were conducted to evaluate time x group interaction for the primary dependent variables specified in the hypotheses above. Hypothesis 1 used repeated measures and compared four conditions to determine if there was a significant improvement from pre to post testing. Validity checks were also used to suppress the sample size and only include participants who were paying attention to the relevant working memory training task. Hypothesis 2 used independent samples t-tests to determine the difference in flow levels between the cybercycle and effortful cybercycle conditions.

RESULTS

A total of 77 participants were recruited and completed the current study. Sixteen of the participants were randomly assigned to the cybercycle and videogame condition, fifteen were placed in the blank screen, working memory training, and the combined cybercycle and working memory training condition. Forty-eight females took part in the study and twenty-nine males, with a mean age of 19.4 years (SD=1.4; range=17-23). Forty freshman, six sophmores, twelve juniors, and sixteen seniors participated in the study. Three participants did not include their class year on the demographic questionnaire. The additional demographic characteristics were displayed in Table 1. The average pre-test and post-test scores for executive functioning were recorded in Table 2. These neuropsychological tests included the Color Trails II, Stroop C, and Digit Span Backwards.

Participants in the cybercycle condition (Low ACE) burned an average of 157 calories with a minimum of 122 calories and a maximum of 233 calories. Those in the blank screen condition burned an average of 154 calories with a minimum of 77 and a maximum of 236. The participants placed in the effortful cybercycle condition (High ACE) burned an average of 140 calories with a minimum of 110 and a maximum of 195. The blank screen condition did not burn calories, for they were not instructed to exercise on the bike. The average and standard deviations of calories burned throughout each group are displayed in Table 3, as well as the additional physiological measures that were examined in each exercise condition.

The participants who were randomly assigned to an exercise condition were given a target heart rate to maintain throughout the entire twenty minute session. When analyzing hypothesis one, if the participant in condition 1 or condition 5 had a maximum heart rate that was within ten beats per minute, their data was used in the results. However, participants who were not able to reach a maximum heart rate that was within ten beats of their target heart rate, were considered to not be exerting enough energy. These results may not be beneficial in the current study if heart rate is a significant measure impacting the cognitive functioning of the individual. In addition, when participants in the low ACE condition and high ACE condition were compared throughout hypothesis 1, the participants who received a mental task had to maintain a 70% correctness on the activity. If they did not achieve this cutoff, they were not included in the current study. Eleven participants in the regular cybercycle condition and eight participants in the combined working memory task and cybercycle condition were able to meet this requirement.

Combined Mental and Physical Exercise Will Show Greater Improvement in Executive Function than All Other Conditions

The videogame condition was not included in the following analyses because the task was not relevant to the current study. The additional four conditions were included in the results. Multivariate tests showed that the effect of the physical and mental exercise conditions on executive function was not significant, $F(3,9) = 1.78$, $p = 0.08$. In addition, the univariate tests were examined to determine if there was a single variable that had a significant impact on the three executive functioning tasks. Although univariate analyses decrease the validity of the statistical tests being performed, this study examines each variable of interest.

The interactive effect of the physical and mental exercise as measured by Digit Span Backwards was not significant, $F(3,57) = 0.96$, $p = 0.42$, participants in the cybercycle condition ($M = 7.16$) did not have a greater improvement in performance when compared to the blank screen condition ($M = 7.30$), the combined working memory training and cybercycle condition ($M = 7.27$), or the working memory training condition ($M = 8.6$) (Table 4). Post-Hoc Tukey tests revealed that there were no significant differences when each of the groups were compared individually (Table 5). However, the results showed that the only major decline in performance was with the combined working memory and exercise condition. This could be explained by the difficulty of multi-tasking on an interactive bike while attempting to complete a working memory task.

The interactive effect of the physical and mental exercise as measured by Stroop C was not significant, $F(3,57) = 1.92$, $p = 0.14$, participants in the cybercycle condition ($M = 34.55$) did not have a greater improvement in time when compared to the blank screen condition ($M = 32.57$), the combined working memory training and cybercycle condition ($M = 33.55$), or the working memory training condition ($M = 30.22$) (Table 4). Post-Hoc Tukey tests revealed that there were no significant difference in Stroop C performance when each of these groups was compared individually (Table 5). Results did show an overall improvement from pre-test to post-test for each of the conditions.

The interactive effect of the physical and mental exercise as measured by Trails 2 was not significant, $F(3,57) = 2.40$, $p = 0.08$, participants in the cybercycle condition ($M = 54.26$) did not have a greater improvement in time when compared to the blank screen condition ($M = 55.88$), the combined working memory training and cybercycle condition ($M = 54.62$), or the working memory training condition ($M = 56.83$) (Table 4). Post-Hoc Tukey tests revealed that there were no significant difference in Trails 2 performance when each of these groups was compared individually (Table 5). Results did show an overall improvement from pre-test to post-test for each of the conditions. This ultimately illustrates that physical exercise, mental exercise, and these two variables combined have an overall positive impact on cognitive functioning.

Hypothesis 1: Comparing Cybercycle Condition (Low ACE) with Effortful Cybercycle Condition (High ACE) - Reached 70% Compliance and Target Heart Rate

To get a pure representation of mental exercise, it was necessary to only include participants who reached 70% correctness in the conditions that were directed to complete the working memory training task. The participants who were unable to perform the mental challenge to the best of their ability were dropped from the analysis and the cognitive effects of exercise on working memory were examined with participants who completed the mental task. Fourteen participants in the cybercycle condition and twelve participants in the effortful cybercycle condition were included in the current analysis. Multivariate tests showed that the effect of exercise on executive function was not significant when comparing these two groups, $F(3,22) = 1.24$, $p = 0.319$. Univariate tests were still examined to determine if the individual neuropsychological tests displayed a significant improvement among groups.

The interactive effect of the exercise conditions as measured by Digit Span Backward was not significant, $F(1,24) = 1.09$, $p = 0.31$, participants in the cybercycle condition ($M = 0.57$) did not improve more in performance compared to the effortful cybercycle condition ($M = -0.33$). The cybercycle condition improved on Digit Span Backwards post-intervention, but the effortful cybercycle condition did worse (Figure 1).

The interactive effect of the exercise conditions as measured by Stroop C was not significant, $F(1,24) = 2.35$, $p = 0.14$, participants in the cybercycle condition ($M = -5.43$) did not improve more in performance compared to the effortful cybercycle condition ($M = -7.94$). Both of these conditions improved overall on their ability to complete the Stroop task of executive functioning, but it was not a significant interaction (Figure 2).

The interactive effect of the exercise conditions as measured by Color Trails 2 was not significant (Figure 3). Participants in the cybercycle condition (*M*=-8.38) did not improve more in performance when compared to the effortful cybercycle condition. Post-Hoc Tukey tests could not be examined because there were only two conditions being assessed on executive function.

Hypothesis 2: Participants in the Effortful Cybercycle Condition are More Likely to Reach a State of Flow than Participants in the Working Memory Only Condition- Which Will Lead to an Increase in Executive Functioning.

An Independent samples t-test revealed that there was a significant difference in the total flow score for cybercycling (M=24.92, SD=4.56) and effortful cybercycling (M=21.73, 2.37); t (23) = 2.16, p = .041. These results suggest that the cybercycle condition (Low ACE) was able to reach a higher state of flow than the effortful cybercycle (High ACE) condition leading to an increase in cognitive functioning. Figure 4 shows the relationship of flow state between the cybercycle condition and effortful cybercycle condition.

Comparing the Stress Levels of Participants in the Cybercycle Condition (Low ACE) with Participants in the Effortful Cybercycle Condition (High ACE)

An Independent samples t-test revealed that there was not a significant difference in the post-stress states for participants in the cybercycle condition (M=23.07, SD=6.27) and the effortful cybercycle condition (M=28.43, SD=11.67); $t(24) = -1.49$, $p = 0.151$. These results suggest that the effortful cybercycle condition (High ACE) felt an increase in stress post-intervention when compared to the cybercycle condition (Low ACE). This could be explained by the additive mental task to the interactive physical activity. The relationship between these two conditions is revealed in Figure 5.

DISCUSSION

The current study examined the cognitive benefits of mental and physical activity combined on a total of 77 undergraduate college students. After a twenty minute acute bout of physical or mental exercise, it was evident that on average participants were improving on tasks of neuropsychological function. Although there seemed to be a trend toward improvement on post-tests, these changes were not significant when comparing the cybercycle (condition 1), blank screen (condition 2), effortful cybercycle (condition 5), and working memory only (condition 6). This could ultimately be due to the small sample size of 15-16 participants per condition.

When participants were given the working memory task to complete in condition 5 or condition 6, they were assessed based upon their ability to multitask while either cybercycling or playing a videogame. It was hypothesized that participants in the effortful cybercycle condition (High ACE) would reveal significant improvements in executive functioning tasks post-intervention when compared to the cybercycle condition (Low ACE). Based upon the results that were collected, it was evident that some participants were not paying attention or did not grasp the overall purpose of the task. These participants who did not receive 70% correctness on the task were dropped from the overall analysis. In addition, participants who were unable to reach their target heart rate at any point during the study were also not included in the sample. Reaching a target heart rate is of great importance while engaging in physical exercise, for it shows that the participant is exerting enough effort to make a significant difference in their cognitive functioning.

After the participants were excluded from the study, the results post-intervention showed insignificant findings on the three tests of executive functioning: Digit Span Backward, Stroop

C, and Trails 2; however, there was a trend toward significance. On the Digit Span Backward and Trails task, the cybercycle (Low ACE) showed greater improvement than the effortful cybercycle (High ACE), which ultimately contradicts the main hypothesis of the study. It is possible that the effortful cybercycle condition could have been too difficult for the participant, leading to less improvement overall on tests of neuropsychological functioning.

It was also hypothesized that because of the mental effort utilized throughout the working memory task, the effortful cybercycle condition would be able to reach a state of flow. After an independent samples t-test was conducted to compare the effortful cybercycle condition and the cybercycle condition, it was evident that the participants who completed the working memory task were unable to fulfill this mental state. Reaching a state of flow requires an individual to completely disengage from the surrounding environment and focus solely on the task at hand. The findings revealed that increasing the mental task is more burdensome and inhibits an individual's ability to reach a higher and more efficient mental state. The current study demonstrated that adding the working memory task contradicted the effects of the traditional cybercycle benefits which led to an overall increase in cognitive functioning. The significant difference between the effortful cybercycling and the traditional cybercycling could be due to the inability for the effortful cybercycle condition to reach a state of flow.

In addition, participants were given a stress questionnaire pre and post intervention to determine the degree to which they feel calm as opposed to stressed out. After an Independent t-test was conducted between the cybercycle condition (Low ACE) and the effortful cybercycle (High ACE) condition, it revealed that participants who were given a mental task while riding on the stationary bike had a higher stress level than the participants who were only given the interactive virtual reality cycling. The difference in stress levels between these two conditions could be a result of additive stress while performing a tedious mental task. The participants could not focus solely on their performance with the cybercycle, but instead had to attend to additional stimuli at one time.

Strengths

There are several strengths of the current study that are worth noting. This study reveals a gap in the literature, for no prior study has combined working memory training tasks with cybercycling to examine the neuropsychological effect. Anderson-Hanley and colleagues (2012) investigated the effects of virtual reality enhanced interactive cycling and found that there was a cognitive benefit after three months of intervention. On the other hand, Anguera (2013) researched videogame training and the ability it has to enhance cognition in the elderly population. The current study combined these two findings to reveal that there are possible benefits when combining a working memory task and cybercycling; however, this preliminary study needs to be investigated in future studies.

Limitations

There were several limitations that may have impacted the overall results of the current study. The first major problem was the single bout of exercise that was being used to assess the cognitive benefits of a particular. Participants who were assigned to a condition had to complete a twenty minute bout of exercise or working memory intervention; however, it is difficult to draw any conclusion when the study does not take place over an extended period of time. Maillot and colleagues (2012) performed a study that examined the physical and cognitive effects of exergaming on older adults. This study extended for a total of 24 hours over the span of 12 weeks. An additional study examined the improvement of executive function in overweight children; however, this intervention followed the participants for a total of three years. As exemplified in prior research studies, it is imperative that multiple bouts of exercise are performed to determine the overall effects of exercise on cognition. It is difficult to determine the changes in executive functioning after a single bout of exercise.

The second major flaw within the current study was the methodological design of the working memory training task. Participants in the working memory only task were directed to use the keyboard and navigate through the trail by using three different keys – one to go straight, left, and right. In addition, they also had to multitask and address whether the objects appearing were located on the left or right side of the pathway and state when they passed a total of ten objects. Participants expressed great difficulty navigating with the keyboard, for they could not control the speed of the videogame. It became extremely difficult for participants to control the movement on the screen as well as perform the multitasking intervention that was being asked of them.

Another key limitation that could have hindered the results was the way in which the schedule was set up for experimenters. There were six experimenters who were conducting the current study; each was given a timeslot to cover throughout the entire study. Prior to conducting the study, each researcher was given a tutorial on how to properly administer the neuropsychological tests and particular intervention that they would be assigned to. In addition, they were also given instructional packets with directions to ensure that there was little diversity among conditions. When looking through files, it was found that one experimenter was administering the Stroop task differently than the other participants. For future studies, I think it is important to have less experimenters conducting the study which will ultimately lead to an increase in validity throughout the entire intervention.

The sample size that was used for the current sample was extremely small because of the limited funds that were available and the amount of time that was given to complete the study. When participants were assigned to seven different conditions, there was less reliability within each group. With such a small sample size it is difficult to see an interaction between different groups.

Future Research

The current study is extending upon prior literature to determine the neuropsychological effects of combining a mental task with physical activity. However, there are limitations within the study that need to be addressed in future research. The sample of participants within the study needs to be increased to determine whether there is a significant difference between interactive virtual reality cycling and adding an additional mental component to the exercise condition. Additionally, the sample size should also be extended to older adults suffering from dementia to determine whether age is a factor leading to the improvement of executive functioning over time. In 2012, Anderson-Hanley and colleagues found a significant improvement for older adults assigned to the Low ACE condition when compared with traditional stationary biking. It is imperative that future studies utilize that type of sample to determine if physical activity and mental exercise have a greater effect on the elderly population.

Additionally, the working memory task that was assigned to the effortful cybercycling condition (condition 5) was extremely boring and repetitive, potentially leading to the inability to reach a state of flow. The participants in this condition also claimed to have increased stress levels due to the overall nature of the task. Future studies should create a working memory task that is more interactive, potentially leading to the participants reaching a higher mental state and a lower stress level. Instead of having participants relay to the examiner the amount of trees they have passed, there should be a more naturalistic and real-life task incorporated into the study. For example, the participants could instead be given directions that would have to be incorporated into the pathway on the screen. The individuals would have to remember where they were told to go (bank or grocery store) and steer into that direction. This would create a more interactive experience for the participant leading to a decrease in stress levels and a possible increase in flow state.

Conclusion

As previously mentioned, the purpose of the current study was to determine the impact of adding a mental component to an interactive virtual reality stationary biking system. The purpose of the initial hypothesis was to determine if there is an added cognitive benefit due to the combination of aerobic and cognitive tasks. Although the findings were insignificant, the results revealed that the Low ACE (cybercycle condition) benefitted more on tests of neuropsychological functioning. To determine whether the relationship is significant, it is important for future studies to utilize a greater sample size throughout these two main conditions. In addition, it was also hypothesized that the participant's ability to reach a flow state would have an impact on their tests of executive functioning. Results showed that there was a significant difference between participants in the low ACE condition and participants in the high ACE condition. Participants in the effortful cybercycle condition were unable to reach a state of flow and were found to have increased stress levels post-intervention. These two factors could ultimately play a major role in the post-intervention tests of executive functioning. The purpose of the current study was to build upon prior research which stated that there is a cognitive benefit for cybercycling and working memory training independent from one another. Combining these two interventions hindered the participant's ability to reach a state of flow and improve on the three tests of executive functioning.

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Table 1. Demographic Characteristics

Mean (SD)				
	Condition 1	**Condition 2**	**Condition 5**	**Condition 6**
Age, years	19 (1.5)	19 (1.2)	20 (1.5)	20 (1.5)
Females (n)	11	7	11	6
Males (n)	5	8	4	9
Medical Factors				
Height, in.	67.3 (3.8)	67.7 (3.9)	65.7 (4.1)	69.2 (4.4)
Weight, lbs.	149.3 (23.9)	165.5 (38.0)	139.5 (25.2)	170.5 (48.3)
BMI	23 (3)	25 (4)	23 (2)	25 (7)
Experience w Videogames (0-4)	2.4 (1.2)	1.8 (1.2)	2.1 (1)	2.3 (1)
Fitness Level				
Pattern of Daily Activity (1-5)	3.7 (1.5)	3.7 (1.5)	4.2 (1.1)	3.7 (1.5)
Minutes of Exercise per Session	53.4 (22.9)	72 (35.5)	53.3 (20.6)	66.7 (26.2)

Condition 1 = Cybercycle use (Low ACE); Condition 2 = Blank Screen; Condition 5 = Effortful Cybercycling (High ACE); Condition 6 = Working Memory task

Table 2. The pre- and post- intervention neuropsychological performance.

Neuropsych Test (PRE)	Color Trails II-A, seconds	Stroop C, seconds	Digit Span Backwards, #'s	**Neuropsych Test (POST)**	Color Trails II-B, seconds	Stroop C, seconds	Digit Span Backwards, #'s
Cond. 1	58 (17)	37 (8.1)	6.9 (2.7)		50 (14)	32 (7.9)	7.4 (3.3)
Cond. 2	62 (18)	35 (7.3)	7.1 (2.6)		50 (11)	30 (4.9)	7.5 (2.2)
Cond. 5	56 (8.8)	37 (8.5)	7.5 (2.9)		53 (8.6)	30 (7.4)	7 (2.6)
Cond. 6	60 (15)	32 (5.7)	8.7 (2.7)		54 (14)	29 (7)	8.6 (2.6)
P-value 1v2	0.54	0.41	0.95		0.89	0.49	0.88
P-value 1v5	0.67	0.99	0.56		0.50	0.48	0.73
P-value 1v6	0.75	**0.04**	0.08		0.51	0.27	0.27
P-value 2v5	0.26	0.42	0.60		0.34	0.88	0.55
P-value 2v6	0.74	0.19	0.10		0.40	0.53	0.23
P-value 5v6	0.40	0.04	0.28		0.91	0.69	0.10

Condition 1 = Cybercycle use (Low ACE); Condition 2 = Blank Screen; Condition 5 = Effortful Cybercycling (High ACE); Condition 6 = Working Memory task

Table 3. Physiological Characteristics for Participants in the Exercise Conditions

Physiological Measures	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**			
	Cond. 1	**Cond. 2**	**Cond. 5**	**P-value (1 v 2)**	**P-value (2 v 5)**	**P-value (1 v 5)**
Distance (miles)	4.5 (0.5)	4.6 (0.8)	4.2 (0.7)	0.62	0.22	0.3
Average Power (watts)	105.9 (26.3)	94.7 (30.3)	91.6 (25.5)	0.29	0.77	0.14
Maximum Power (watts)	443.8(149.3)	317.5(133.3)	351.1 (92.4)	0.02	0.45	0.05
Target Heart rate (bpm)	153.5 (3.1)	153.3 (6.5)	151.6 (6.5)	0.93	0.48	0.32
Average Heart rate (bpm)	149.3 (13.8)	140.9 (16.2)	143 (12.9)	0.13	0.7	0.21
Maximum Heart rate (bpm)	166.9 (15)	165.2 (16.2)	162.4 (15)	0.78	0.64	0.42
Average Speed (mph)	13 (1.6)	12.7 (2.2)	12.5 (1.3)	0.62	0.79	0.33
Maximum Speed (mph)	21.3 (4.1)	18.7 (3.5)	19.4 (2.6)	0.08	0.56	0.15
Calories Burned	158.9 (32.7)	153.9 (42.8)	139.9 (26.3)	0.72	0.32	0.11

Condition 1 = Cybercycle use (Low ACE); Condition 2 = Blank Screen; Condition 5 = Effortful Cybercycling (High ACE)

* Note: Condition 6 was the working memory only task which did not entail riding the cybercycle. There were no physiological measures that were recorded throughout this intervention.

Table 4. Neuropsychological Outcomes Following the 20 Minute Intervention

	Mean	Mean	Mean	Mean	P-values
	Cond. 1	**Cond. 2**	**Cond. 5**	**Cond. 6**	
All Participants	***n* = 16**	***n* = 15**	***n* = 15**	***n* = 15**	
Digit Span Backward	7.16	7.27	7.27	8.63	0.42
Stroop C	34.55	32.57	33.55	30.22	0.12
Color Trails 2	54.26	55.88	54.62	56.83	0.08

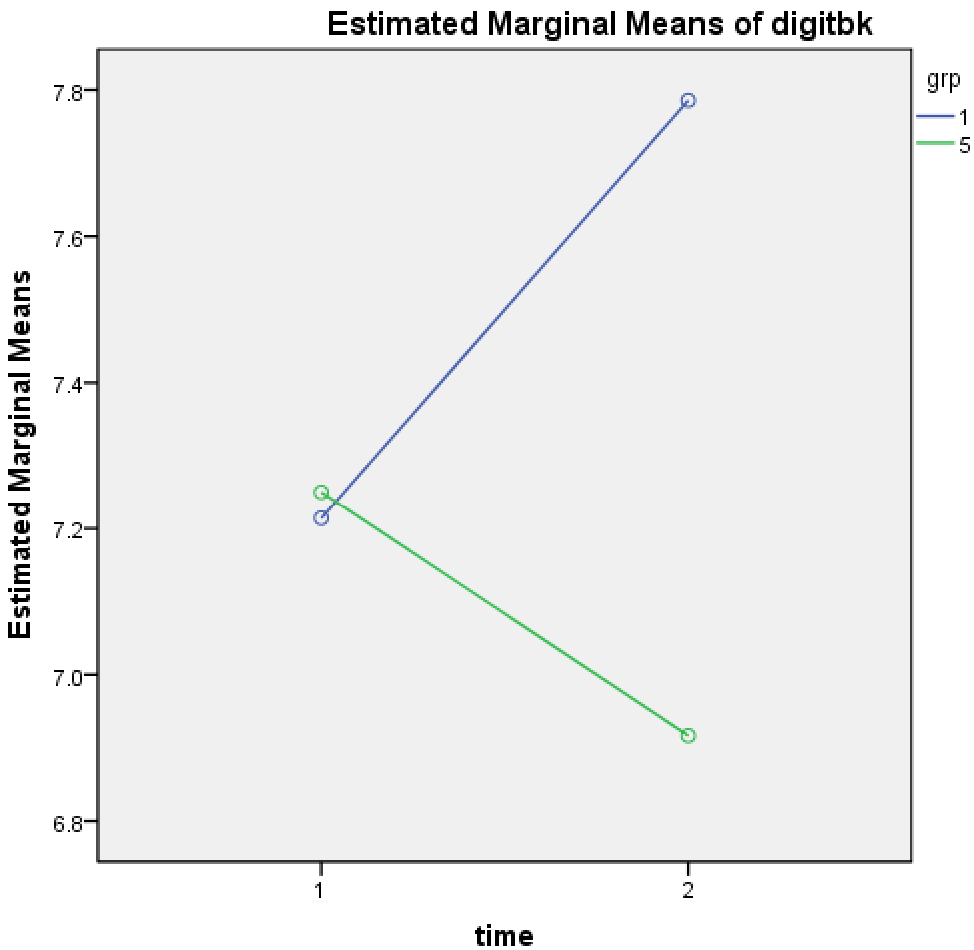
Condition 1 = Cybercycle use (Low ACE); Condition 2 = Blank Screen; Condition 5 = Effortful Cybercycling (High ACE); Condition 6 = Working Memory task

Table 5. Post-Hoc Tukey tests to Compare Individual Groups on Differences in Executive Function

Tests of Executive Functioning	1 v. 2	1 v 5	1 v 6	2 v 5	2 v 6	5 v 6
Digit Span Backward	1.00	1.00	0.38	1.00	0.46	0.46
Stroop C	0.85	0.98	0.29	0.98	0.78	0.53
Color Trails 2	0.99	1.00	0.94	0.99	1.00	0.97

Condition 1 = Cybercycle use (Low ACE); Condition 2 = Blank Screen; Condition 5 = Effortful Cybercycling (High ACE); Condition 6 = Working Memory task

Figure 1. Comparing the effects of the cybercycle condition with the effortful cybercycle condition on the Digit Span Backward task.



Key: Condition 1 = Cybercycle; Condition 5 = Working Memory Training and Cybercycle

Figure 2. Comparing the effects of the cybercycle condition with the effortful cybercycle condition on the Stroop C task.

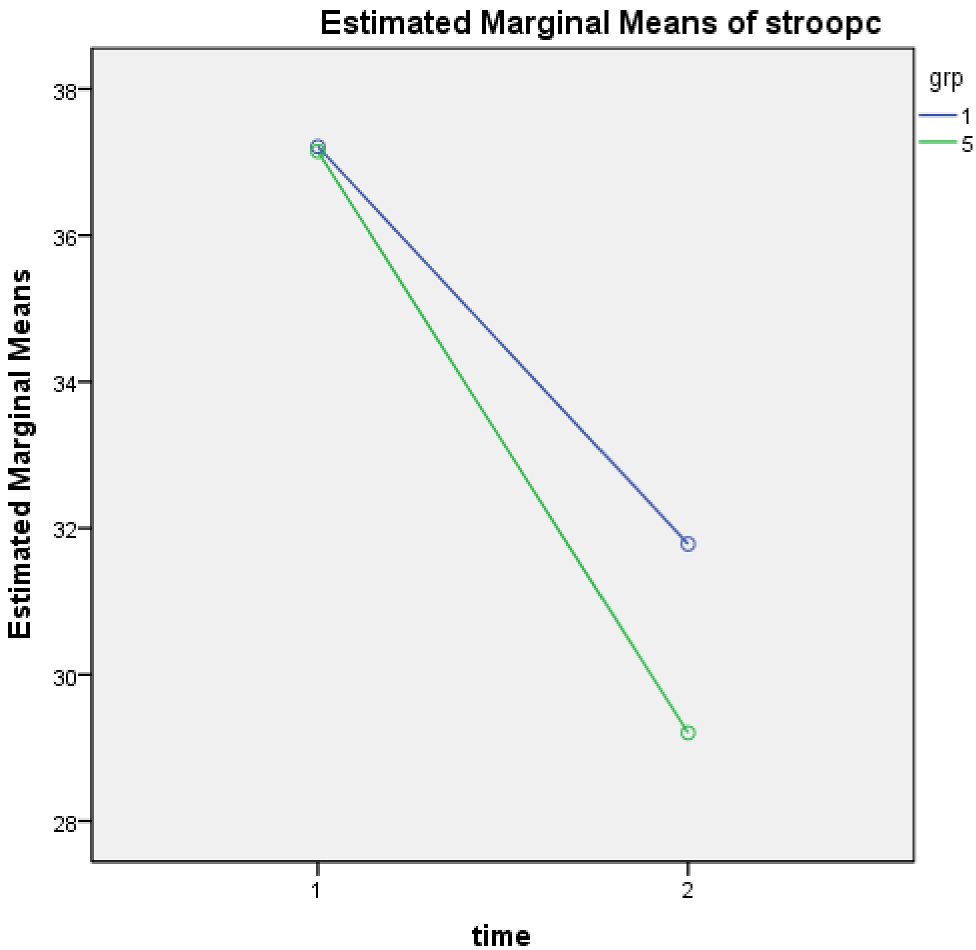


Figure 3. Comparing the effects of the cybercycle condition with the effortful cybercycle condition on the Trails 2 task.

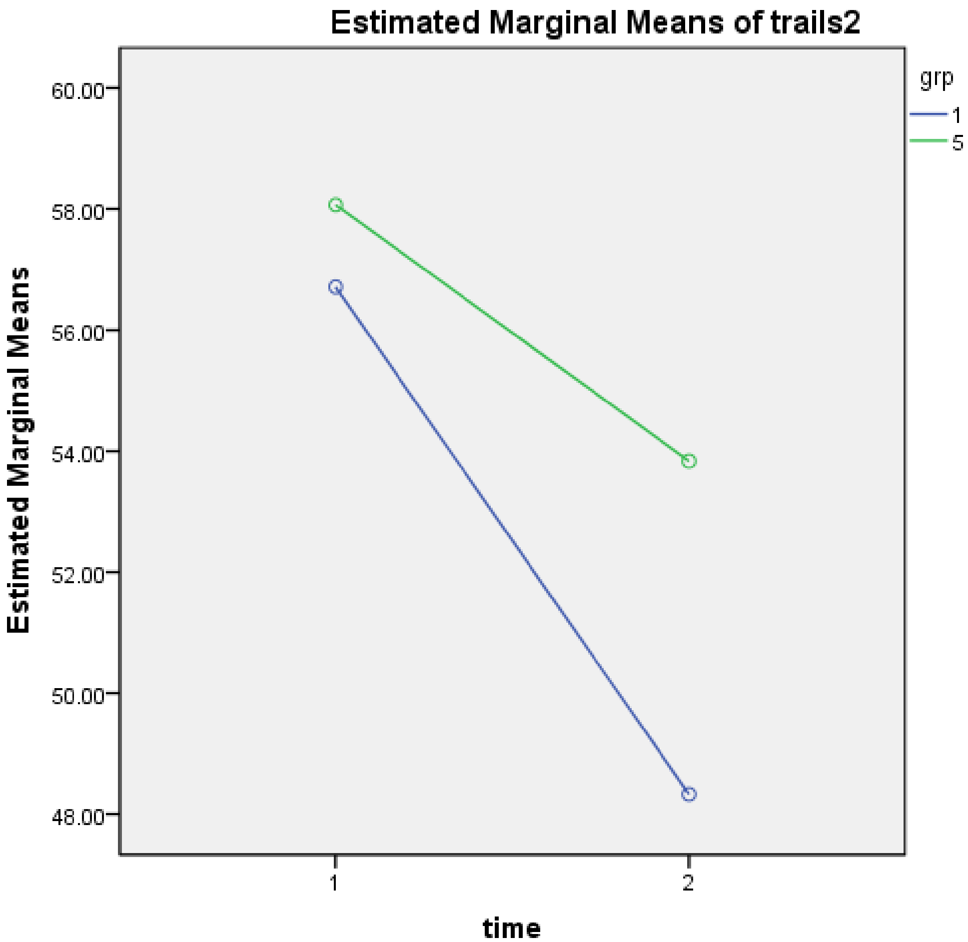


Figure 4. Comparing the Flow State between the Cybercycle (Low ACE) condition and the Effortful Cybercycle condition (High ACE)

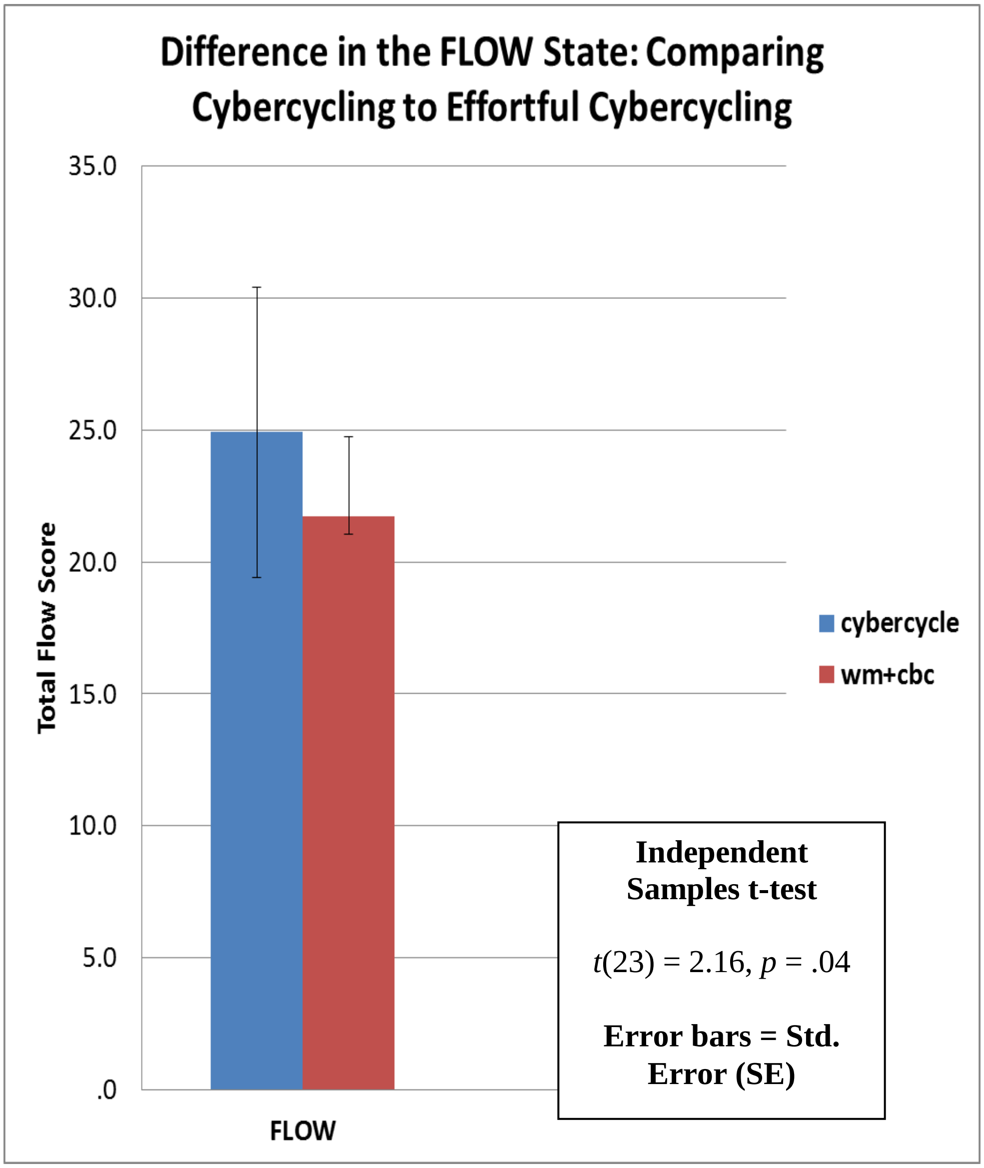
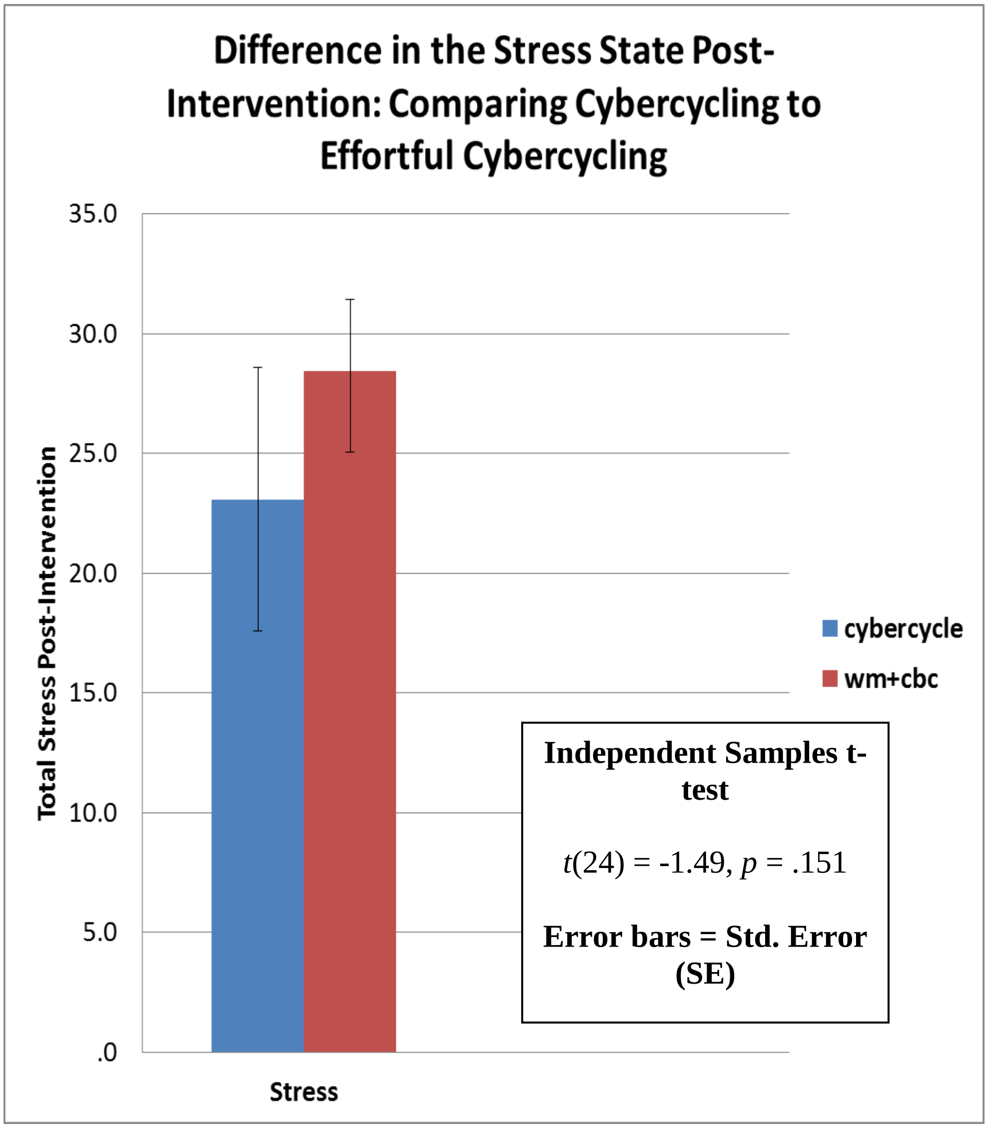


Figure 5. Comparing the Flow State between the Cybercycle (Low ACE) condition and the Effortful Cybercycle condition (High ACE)



Appendix A
Protocol Instructions

Participant ID# _______ Date _______________
Pre Evaluation Time (please note am or pm too) ________________

Instructions Form

______ Welcome participant to the study.

______ Give participant a copy of the Informed Consent Form.

Please read this Informed Consent form carefully and sign at the bottom. If you have any questions, do not hesitate to ask.

______ Administer Demographic Questionnaire and Exercise History Questionnaire

Please fill out these questionnaires to the best of your ability. Remember that all answers will remain confidential.

______Administer Psychological Stress Measure (PSM -9; Lemyre et al., 2009) & FLOW Questionnaire

Please fill out these questions to the best of your ability. All answers will remain confidential.

_____ Administer Color Trails A (time to complete if less than 60 sec or stop participant at 60 sec and record # correct)

Be sure to be ready with the stopwatch, even a one second difference in recording time can be significant..

PRACTICE: Color Trails A-1
In this box are different colored circles with numbers in them. When I say "begin," I want you to take this pen and connect the circles by going from 1 *(point to the 1),* **2** *(point to the 2),* **3** *(point to the 3)***, and so on, until you reach the end. I want you to connect the circles in the correct order as quickly as you can, without lifting the pen from the paper. If you make a mistake, I will point it out. When I do, I want you to move the pen back to the last correct circle and continue from there. The line that you draw must go through the circles and must do so in the correct order. Do you have any questions? Okay, let's practice. Put your pen here where this hand tells you to start. When I say "begin," connect the circles in order as quickly as you can until you reach the circle next to the hand telling you to stop. Ready? Begin.** *(Begin timing as soon as you detect movement toward the first circle.)*

TEST: Color Trails A-2
Now I have a sheet with several more numbers and circles. Connect the circles in order like you did just a moment ago. Again, work as quickly as you can, and do not lift the pen from the paper as you go. Make sure that your lines touch the circles. *Point to the first circle and say the following:* **You will start here, where the hand tells you to start, and end where the hand tells you to stop. Ready? Begin.** *(Begin timing as soon as you detect movement toward*

the first circle. Be sure to record # of dot just completed at 60 seconds, as well as time to complete all).

Record circle color and number at 60 seconds: _____

Record time to complete (in seconds): _____

_____ Administer the Stroop Task (PROSPER version – 40 items)

Before showing the examinee any of the cards, say:

COLOR BLOCKS:
I am going to show you a few different pages. On this first page, there are some colored blocks. Please tell me the names of the colors you see on this top, sample row (point to the row)**.**

If necessary, clarify that the names to use are: red, blue & green. If the examinee cannot distinguish the colors, perhaps due to color-blindness, move on to the next task. If the examinee completes the sample line successfully, say:

Good. Now I want you to tell me the names of each color block starting here and going as quickly as you can, without making mistakes, across the row and down to the next line and across, etc., until you finish all the rows (point to the end)**. Are you ready? Go.** (Be sure to start & stop the timer precisely. Mark all answers on your record sheet so that you can tally the number of errors later. Examinee can self-correct, but do not prompt for corrections)**.**

BLACK WORDS:
Ok good, on the next page you will see that the task is similar, but slightly different. Here, read the words as quickly as you can. Please try the sample line (point)**.**

Fine. Now I want you to start here (point) **and read across as quickly as you can without making mistakes. Again, go across each row and then down until you finish all the rows** (point to the end)**. Are you ready? Go.**

COLORED WORDS (incongruous/interference):
Good. On this last page, your task is to tell me the color of the ink and ignore the written word. (Feel free to empathize if the examinee laughs, gasps, etc. – e.g., say something like: **I realize this is getting more challenging, but do the best you can). Please try the sample line.**

Fine. *(If not, please explain again and repeat practice until clear understands, or abandon task).* **Start here** (point) **and read across and then down as quickly as you can without making mistakes until the end** (point)**. Are you ready? Go.**

_____ Administer Digit Span (digits forward)

Read numbers at rate of one second per number, with downward intonation at end. Be sure to record <u>all</u> responses whether right or wrong. Discontinue after 2 failures of the same length of digits.

I am going to say some numbers. Then when I am through, I want you to repeat them right after me. For example, if I say 8-9 you will say 8-9. You'll just say exactly what I say.

_____ Administer Digit Span (digits backward).

Read numbers at rate of one second per number, with downward intonation at end. Be sure to record all responses whether right or wrong. Discontinue after 2 failures of the same length of digits.

Now I am going to say some more numbers. But this time when I stop, I want you to say them backward. For example, if I say 7-9, what would you say?

______ EXERCISE CONDITION 1: CYBERCYCLE & TRAIL

INSTRUCTIONS FOR CYBERCYCLE:
You will be completing 20 minutes of biking on a trail. To go forward and move around the course you start pedaling. The bars on either side of you are what you will use to steer. To steer right, you will lift the left handlebar and push down the right. To steer left you will lift the right handlebar and push down the left. Increasing the gear is going to make you move faster on the course and also raise your heart rate. To change the gears of the bike use to two red buttons located on the handlebars. To increase the gear you press down on the left red button. To decrease the gear you press down on the right red button. The gear indicator is located on the bottom right corner (point to where it is located). **Do you have any questions?**

______ Measure resting heart rate and calculate the participants target heart rate.
Before we begin, please hold on to the handlebars so that we can get a reading of your resting heart rate. Record it on this sheet and on the attached exercise table.

THR = (220 – age – RHR) x .60 + RHR (record on the attached exercise table)

Ok. During this exercise session, we want you to try to reach and maintain an exercise intensity equal to 60% of your heart rate reserve during a 20 min exercise bout. In order to achieve this, try your best to exercise at a pace so that your heart rate is around _________ beats per minute .To help reach and maintain your target heart rate, you may adjust the gears to change pedaling resistance. Remember that increasing the gear will help raise heart rate, make you go faster in the game. The bottom right of the screen tells you which gear you are on. I will incrementally let you know if you have reached your target heart rate and will further instruct you to maintain your heart rate, or to increase the resistance of the bicycle or pedal faster to raise your heart rate.

Let me know when you are ready to begin. Once participant says they are ready:
- Select the trail course from the cybercycle menu (Called Evening Bliss)

Now you can begin exercising. (Start stopwatch for 20 mins)

______ EXERCISE CONDITION 2: STATIONARY BIKE WITH BLANK SCREEN

INSTRUCTIONS FOR STATIONARY BIKE: **Here is the stationary bike that you will be using to exercise. Please sit on the bicycle and adjust the seating using the red bar in front of the seat so that you are comfortable. The bars on either side of you are the handlebars. The red buttons on the handlebars change the gears of the bike, and the gear indicator is located in**

the bottom-right corner of the screen. For both handlebars, the right red button decreases the gear and the left red button increases the gear.

______ Measure resting heart rate and calculate the participants target heart rate.
Before we begin, please hold on to the handlebars so that we can get a reading of your resting hear rate. Record it on this sheet and on the attached exercise table.

THR = (220 – age – RHR) x .60 + RHR (record on the attached exercise table)

Let me know when you are ready to begin.

(Start stopwatch for 20 mins)

___EXERCISE CONDITION 3: MINDFUL CYBERCYCLING

INSTRUCTIONS FOR CYBERCYCLE: **You will be cycling for 20 minutes and steering through a trail. Please sit on the bicycle and adjust the seating using the red bar in front of the seat so that you are comfortable. The bars on either side of you are the handlebars. The red buttons on the handlebars change the gears of the bike, and the gear indicator is located in the bottom-right corner of the screen. For both handlebars, the right red button decreases the gear and the left red button increases the gear. To steer right, you will lift the left handlebar and push down the right. To steer left you will lift the right handlebar and push down the left. Increasing the gear is going to make you move faster on the course and also raise your heart rate. Do you have any questions?**

INSTRUCTIONS FOR MINDFUL MEDITATION: **You will be listening to a pre-recorded audio meditation track. It's objective is to guide you into a meditative state and into a deeper level of mind. Try your best to follow the track. Relax, and if you notice your thoughts start to wander, acknowledge the thoughts, and bring yourself back to the guided meditation. Focus on the trail and do your best to steer while following the guided meditation. Do you have any questions?**

EXERCISE CONDITION 4: MINDFUL MEDITATION

INSTRUCTIONS FOR MINDFUL MEDITATION: **You will be listening to a pre-recorded audio meditation track. It's objective is to guide you into a meditative state and into a deeper level of mind. Sit comfortably on the bike and relax your body. Try your best to follow the track. Relax, and if you notice your thoughts start to wander, acknowledge the thoughts, and bring yourself back to the guided meditation.**

___EXERCISE CONDITION 5: COGNITIVE TRAINING + CYBERCYLING

INSTRUCTIONS FOR CYBERCYCLE: **You will be cycling for 20 minutes and steering through a trail. Please sit on the bicycle and adjust the seating using the red bar in front of the seat so that you are comfortable. The bars on either side of you are the handlebars. The red buttons on the handlebars change the gears of the bike, and the gear indicator is located in the bottom-right corner of the screen. For both handlebars, the right red button decreases the gear and the left red button increases the gear. To steer right, you will lift the left handlebar and push down the right. To steer left you will lift the right handlebar and**

push down the left. You will be cycling through a trail called evening bliss. Do your best to keep within the perimeter of the trail by adjusting the handlebars. Increasing the gear is going to make you move faster on the course and also raise your heart rate. Do you have any questions?

INSTRUCTIONS FOR COGNITIVE TRAINING: **You will be given a cognitive task to complete while CyberCycling through the Evening Bliss trail. A sign only qualifies as a sign if it is facing you on the trail. When you are biking on the trail and come to either a lamppost or a sign, say outloud "Right" or "Left" based on the side of the trail in which they appear. While you are doing this, also try to keep track in your head how many lampposts and signs you have seen. When you reach ten of these items, say outloud "ten"… "twenty" … "thirty" … etc. Do your best to keep track of how many are appearing. This is a difficult task, so try your best not to get discouraged. Do you have any questions?**

___EXERCISE CONDITION 6: COGNITIVE TRAINING ALONE

INSTRUCTIONS FOR COGNITIVE TRAINING: **You will be asked to sit on the stationary bike and you will be given a cognitive task to complete. A sign only qualifies as a sign if it is facing you on the trail. When you are biking on the trail and come to either a lamppost or a sign, say outloud "Right" or "Left" based on the side of the trail in which they appear. While you are doing this, also try to keep track in your head how many lampposts and signs you have seen. When you reach ten of these items, say outloud "ten"… "twenty" … "thirty" … etc. Do your best to keep track of how many are appearing. This is a difficult task, so try your best not to get discouraged. Do you have any questions?**

___EXERCISE CONDITION 7: VIDEOGAME ALONE

INSTRUCTIONS FOR COGNITIVE TRAINING: **You will be asked to sit on the stationary bike and you will be given a videogame to complete. Your task will be to get a high score. You will pedal and steer toward a coin, once through it, you can follow the arrow to find a matching color dragon. Avoid the water and remember you can down-shift if you hit a hill. Do you have any questions?**

______ Offer participant a glass of water & Administer Attentional Focus Questionnaire.
--------- Administer the Psychological Stress Measure (PSM -9; Lemyre et al., 2009) & FLOW
Please fill out these questionnaires to the best of your ability.

All Conditions:
You will now take the same neuropsych tests you completed earlier. After we are done with the evaluations, we will move on to the final part of the study. Do you have any questions?

_____ Administer Color Trails B (time to complete if less than 60 sec or stop participant at 60 sec and record # correct)

Be sure to be ready with the stopwatch, even a one second difference in recording time can be significant..

PRACTICE: Color Trails B-1
In this box are different colored circles with numbers in them. This time I want you to take the pen and connect the circles in order by going from *this* color 1 *(point to the pink 1)***, to *this***

color 2 *(point to the yellow 2)***, to *this* color 3** *(point to the pink 3)***, and so on, until you reach the last number next to the hand telling you to stop.** *Take the pen and point to the example below the box as you say the following:* **Notice that the color changes each time you go to the next number. I want you to work as quickly as you can. Do not lift the pen from the paper once you have started. If you make a mistake, I will point it out. When I do, I want you to move the pen to the last correct circle and continue from there. As before, the line you draw must go through the circles in the correct order. Do you have any questions? Okay, let's practice. Put your pen here next to the hand telling you to start. When I say "begin," connect the circles in order as quickly as you can, changing from one color to the next, until you reach the hand telling you to stop, Ready? Begin.** *(Begin timing as soon as you detect movement toward the first circle.)*

TEST: Color Trails B-2
Now I have a sheet with several more numbers and colored circles. Connect the circles like you did just a moment ago. Again, work as quickly as you can. *Point to the first circle and say the following:* **You will start here, where the hand tells you to start, and end where the hand tells you to stop. Ready? Begin.** *(Begin timing as soon as you detect movement toward the first circle. Be sure to record # of dot just completed at 60 seconds, as well as time to complete all).*

Record circle color and number at 60 seconds: _____

Record time to complete (in seconds): _____

_____ Administer the Stroop Task (PROSPER version 2-alternate form – 40 items)

Before showing the examinee any of the cards, say:

COLOR BLOCKS:
I am going to show you a few different pages. On this first page, there are some colored blocks. Please tell me the names of the colors you see on this top, sample row (point to the row)**.**

If necessary, clarify that the names to use are: red, blue & green. If the examinee cannot distinguish the colors, perhaps due to color-blindness, move on to the next task. If the examinee completes the sample line successfully, say:

Good. Now I want you to tell me the names of each color block starting here and going as quickly as you can, without making mistakes, across the row and down to the next line and across, etc., until you finish all the rows (point to the end)**. Are you ready? Go.** (Be sure to start & stop the timer precisely. Mark all answers on your record sheet so that you can tally the number of errors later. Examinee can self-correct, but do not prompt for corrections)**.**

BLACK WORDS:
Ok good, on the next page you will see that the task is similar, but slightly different. Here, read the words as quickly as you can. Please try the sample line (point)**.**

Fine. Now I want you to start here (point) **and read across as quickly as you can without making mistakes. Again, go across each row and then down until you finish all the rows** (point to the end)**. Are you ready? Go.**

COLORED WORDS (incongruous/interference):

Good. On this last page, your task is to tell me the color of the ink and ignore the written word. (Feel free to empathize if the examinee laughs, gasps, etc. – e.g., say something like: **I realize this is getting more challenging, but do the best you can). Please try the sample line.**

Fine. *(If not, please explain again and repeat practice until clear understands, or abandon task).* **Start here** (point) **and read across and then down as quickly as you can without making mistakes until the end** (point)**. Are you ready? Go.**

_____ Administer Digit Span Alternate Form (digits forward)

Read numbers at rate of one second per number, with downward intonation at end. Be sure to record all responses whether right or wrong. Discontinue after 2 failures of the same length of digits.

I am going to say some numbers. Then when I am through, I want you to repeat them right after me. For example, if I say 8-9 you will say 8-9. You'll just say exactly what I say.

_____ Administer Digit Span Alternate Form (digits backward).

Read numbers at rate of one second per number, with downward intonation at end. Be sure to record all responses whether right or wrong. Discontinue after 2 failures of the same length of digits.

Now I am going to say some more numbers. But this time when I stop, I want you to say them backward. For example, if I say 7-9, what would you say?

______ Debrief and compensate participant.

Give the participant the debriefing form and tell them to read through it. At the end please thank them for their participation.

Appendix B: Pre-Intervention

Informed Consent

Potential Effects of CyberCycling Versus Regular Cycling on Cognition

Our names are Emma Stein and Shannon Crowley and we are students at Union College. We are inviting you to participate in a research study. Involvement in the study is voluntary, so you may choose to participate or not. A description of the study is written below.

We are interested in learning more about the effects of physical exercise and varied mental stimulation on cognition, particularly exercise that involves virtual reality. You will be randomly assigned to one of seven groups: 1) Stationary cycling, 2) Cybercycling (cycling with virtual reality), 3) Mindful Cybercycling, 4) Mindful Meditation (without exercise), 5) Working memory training while cybercycling, 6) Working memory training alone, and 7) a videogame alone. Before and after each twenty minute condition, you will be asked to complete a cognitive evaluation, which will include a paper and pencil evaluation of cognitive function. Total participation will take approximately an hour. The risks to you of participating in this study are minimal and are typical to any acute bout of aerobic exercise. This can include sweating and muscle discomfort. These risks will be minimized by participating in the study only if you are in good health. Exercise should be stopped if you feel sharp pain, dizziness, or shortness of breath. Water will be provided for hydration at anytime during the study and exercise will be completed at your own pace as you strive to reach your target heart rate. If you no longer wish to continue, you have the right to withdraw from the study, without penalty, at any time.

All information will be kept confidential through study identification numbers and results will be de-identified and/or reported in aggregate form. If you have any questions involving the nature of the research, research subject's rights and/or whom to contact in the case of a research related injury, please contact: 1) Emma Stein, steine@union.edu,518-526-8355; or 2) Shannon Crowley, crowleys@union.edu, 518-281-4979; or 3) Professor Anderson-Hanley, andersoc@union.edu, 518- 388-6355.

I understand that during the debriefing session I will be given information about the experiment and have the opportunity to ask questions.

By signing below, you indicate that you understand the information printed above, and that you wish to participate in this research study.

______________________________________ ______________________

Signature of participant Date

____

Printed name of participant

______________________________________ ______________________

Name of investigator Date

Pre - Demographic Questionnaire

Participant ID#_____________

1) Age: ___________

2) Sex: M F

3) Height:__________________(ft/in) Weight:__________________(lbs.)
(*Note: Remember that all information will remain confidential. Please write your height and weight as accurately as possible or to the best of your knowledge.*)

4) Class Year:____________________

5) Major/Minor:__________________________

6) Ethinicity (circle as many as apply):

Caucasian/White	African-American/Black
Hispanic-American	Asian-American
Native American	Other: _______________

7) Did you participate in any varsity athletic team(s) in high school? Yes No

If yes, please specify:____

8) Have you participated in any varsity athletic team(s) in college? Yes No

If yes, please specify:____

Which hand do you write with? ____________________________________

Which hand do you use to throw a ball? ____________________________________

At this time, how much experience have you had with a stationary exercise bike?

1	2	3	4	5
none never used one	very rarely used	occasionally used	used pretty regularly	lots used almost daily

At this time, how much experience have you had with videogames?

1	2	3	4	5
none never used one	very rarely used	occasionally used	used pretty regularly	lots used almost daily

Pre - Exercise History Questionnaire

Participant ID# ____________________

Which one of the five physical activity categories reflects your usual pattern of daily physical activity? Please check the box next to each level of physical activity.

- □ **Level 1**: Inactive or little activity other than usual daily activities.
- □ **Level 2**: Regular (>5 days/week) participation in physical activities for at least 10 min at a time that require low levels of exertion resulting in only slight increases in breathing and heart rate.
- □ **Level 3**: Engage in aerobic exercises (e.g. brisk walking, joggning or running, cycling, swimming, or vigorous sports) at a comfortable pace for 20-60 min per week.
- □ **Level 4**: Participate in aerobic exercises at a comfortable place for 1-3 hour per week.
- □ **Level 5**: Participate in aerobic exercises at a comfortable pace for over 3 hours per week.

Please answer the following questions to the best of your ability.

1) Approximate length (min) of a single session of exercise ________________

2) Identify which type(s) of exercise of which you typically participate.

- □ Strength/Resistance Exercise (e.g. weightlifting)
- □ Flexibility Training/Exercise (e.g. static or dynamic stretching)
- □ Stamina and Endurance Exercise (e.g. cardiovascular exercise, all types of aerobic exercise)
- □ Balance Exercise (e.g. Yoga)

3) Rate the intensity at which you typically exercise:

Low Intensity Moderate/Self-Paced Intensity High Intensity

4) What is your reason for exercising? (please circle all that apply)

To lose weight To stay healthy Because it is enjoyable Other

If other, please specify:____

Pre - Psychological Stress Measure

Participant ID# ____________________

Mark the number that best indicated the degree to which each statement applies to you recently.

Not at all Not really Very Little A Bit Somewhat Quite a bit Very Much
Extremely
1 2 3 4 5 6 7 8

1. I feel calm	1 2 3 4 5 6 7 8
2. I feel rushed; I do not seem to have enough time	1 2 3 4 5 6 7 8
3. I suffer from physical aches and pains: sore back, headaches, stiff neck, stomach aches	1 2 3 4 5 6 7 8
4. I feel preoccupied, tormented or worried	1 2 3 4 5 6 7 8
5. I feel confused; my thoughts are muddled; I lack concentration and I cannot focus my attention	1 2 3 4 5 6 7 8
6. I feel full of energy and keen	1 2 3 4 5 6 7 8
7. I feel a great weight on my shoulders	1 2 3 4 5 6 7 8
8. I have difficulty controlling my reactions, emotions, moods or gestures	1 2 3 4 5 6 7 8
9. I feel stressed	1 2 3 4 5 6 7 8

Appendix C: Post-Intervention

Psychological Stress Measure

Participant ID# ____________________

Mark the number that best indicated the degree to which each statement applies to you recently.

Not at all	Not really	Very Little	A Bit	Somewhat	Quite a bit	Very Much	Extremely
1	2	3	4	5	6	7	8

1. I feel calm	1 2 3 4 5 6 7 8
2. I feel rushed; I do not seem to have enough time	1 2 3 4 5 6 7 8
3. I suffer from physical aches and pains: sore back, headaches, stiff neck, stomach aches	1 2 3 4 5 6 7 8
4. I feel preoccupied, tormented or worried	1 2 3 4 5 6 7 8
5. I feel confused; my thoughts are muddled; I lack concentration and I cannot focus my attention	1 2 3 4 5 6 7 8
6. I feel full of energy and keen	1 2 3 4 5 6 7 8
7. I feel a great weight on my shoulders	1 2 3 4 5 6 7 8
8. I have difficulty controlling my reactions, emotions, moods or gestures	1 2 3 4 5 6 7 8
9. I feel stressed	1 2 3 4 5 6 7 8

Post – Questionnaire

Instructions: After your exercise workout, please use the following scale to indicate the extent to which each word below describes how you feel at this moment in time (right after finishing your exercise). Record your responses by circling one number next to each word.

	Do Not Feel	Feel Slightly	Feel Moderately	Feel Strongly	Feel Very Strongly
Refreshed	0	1	2	3	4
Calm	0	1	2	3	4
Fatigued	0	1	2	3	4
Enthusiastic	0	1	2	3	4
Relaxed	0	1	2	3	4
Energetic	0	1	2	3	4
Happy	0	1	2	3	4
Tired	0	1	2	3	4
Revived	0	1	2	3	4
Peaceful	0	1	2	3	4
Worn-out	0	1	2	3	4
Upbeat	0	1	2	3	4

On the scale below, mark the amount of "**mental effort**" that you were aware of using during your exercise session. That is, how hard you had to intentionally focus, concentrate or otherwise engage your mind to meet the challenge of the exercise task.

0 ———————————————————————————— 100

no mental effort — **very challenging** mental effort

On the scale below, mark the amount of "**physical effort**" that you were aware of using during your exercise session. That is, how hard you had to intentionally pedal, push, or otherwise engage your body to meet the challenge of the exercise task.

0 ———————————————————————————— 100

no physical effort — **very challenging** physical effort

On the scale below, mark the amount that your thoughts focused on bodily exercise experiences (such as sweating, fatigue, etc.), during your exercise session.

0 ———————————————————————————— 100

not thinking about bodily exercise experiences — **thinking** about bodily exercise experiences

Are there any unusual circumstances affecting your rating (feelings above) today?

____

Thinking about the past week, on average, how much do you usually enjoy your workout on the cybercycle? (circle one)

not at all!	a little bit	pretty well	very much	love it!

Thinking about the past week, on average, how has your sleep been? (circle one)

terrible	not good	pretty good	really good	excellent

Please feel free to note anything else you think we should know about you, your progress on the cyberycle, etc.:

____

Post – Flow Questionnaire

Date: __________ ID#: ________

Please consider your most recent study exercise session in rating each of the below statements. Place a checkmark √ to indicate your level of agreement with each statement.

		strongly disagree 1	2	3	4	strongly agree 5
1	I performed automatically, without thinking too much.					
2	I was challenged, but I believed my skills would allow me to meet that challenge.					
3	The experience was extremely rewarding.					
4	I did things spontaneously and automatically without having to think.					
5	Things just seemed to happen automatically.					
6	I had total concentration.					
7	The experience left me feeling great.					
8	Time seemed to alter (i.e., to either slow down or speed up).					
9	It was no effort to keep my mind on what was happening.					
10	I really enjoyed the experience.					
11	I felt just the right amount of challenge.					
12	My attention was focused entirely on what I was doing.					
13	I lost my normal awareness of time.					
14	The way time passed seemed to be different from normal.					
15	I had no difficulty concentrating.					
16	The challenge and my skills were at an equally high level.					

(Payne et al., 2012; 5 subscales - MAA, CO, CS, TT, AE)

Debriefing Form

Potential Effects of Altering Cognitive Stimulation in Cognitive Training CyberCycling Versus Mindfulness CyberCycling

Our names are Emma Stein and Shannon Crowley and we are students are Union College. We would like to thank you for participation in this study. The purpose of this study was to learn more about the effects of mindful meditation and cognitive training tasks on cognition while either combined with cybercycling or separate from exercise. Participants were randomly assigned to 1 of 7 conditions, that had varied types of mental stimulation, ranging from neutral control conditions, to effortful cognitive task engagement while doing physical exercise, or meditative engagement that might facilitate a fascile flow state. Each of these conditions were investigating the effect on the cognition. Before and after each of these conditions, participants were asked to complete the same set of cognitive tasks. Participants were also asked to complete a Physical Activity Questionnaire, in order to assess if physical fitness level has an effect on performance.

Please refrain from sharing any information in this statement with anyone else, particularly other participants of the study that have not yet finished testing, as this could affect the results of the study. If you have any additional questions about any other parts of the study, please feel free to ask any questions now or contact either of us by phone or email: Emma Stein – 518-526-8355 or steine@union.edu; Shannon Crowley – 518-281-4979 or crowleys@union.edu.

Thank you,

Emma Stein and Shannon Crowley
Union College '14